RESEARCH DEPARTMENT

C.W. INTERFERENCE WITH TELEVISION: ITS REDUCTION BY MEANS OF FREQUENCY MODULATION

Report No. T-064

(1956/41)

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SUMMARY

This report has been written as the result of work carried out on a proposal by E.P. Wethey to reduce the visible effect of c.w. interference on a television picture. The proposal relies on the principle that if an interference pattern is broken up by the use of frequency modulation at the transmitter, the protection requirements can be somewhat relaxed.

The report describes the experiments carried out, and indicates that under certain restricted conditions an improvement of between 3 and 5 dB can be obtained, but that in general the method would not be advantageous.

1. INTRODUCTION

Investigations have been carried out both in the U.S.A. and in this country concerning the effects of c.w. interference upon monochrome and N.T.S.C.-type colour television transmissions. Recommendations have been made[1, 2] for the protection ratios required for both types of transmission in terms of the subjective criterion "just tolerable for less than 10 per cent of the time" and these are summarised by the idealised curves shown in Fig. 1. These curves were derived from experiments carried out in terms of the "just perceptible" criterion.

A proposal made by E.P. Wethey[3] suggests that if the vision carrier of the wanted signal is subjected to small periodic deviations of frequency, in a manner such as to cause "break-up" of the observed interference patterns, it may be possible to relax the protection requirements against c.w. interference. This implies that the wanted vision carrier undergoes two forms of modulation simultaneously. First, the carrier is amplitude modulated by the normal video waveform, and, second, it is frequency modulated, with a small deviation, by a suitable low frequency signal.

The report describes experiments carried out to test the effectiveness of the above proposal.

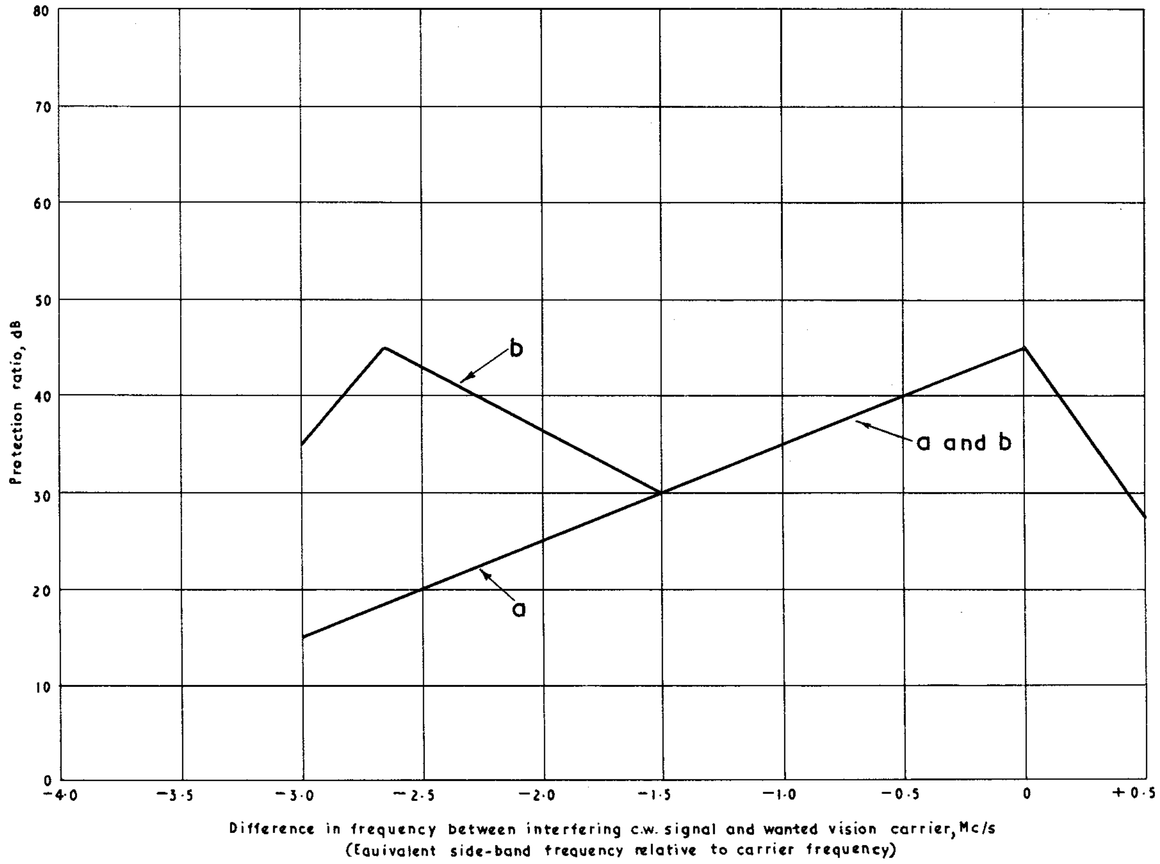

Fig. 1

Curve (a) - Agreed protection ratios for a monochrome receiver receiving a monochrome transmission

Curve (b) - Protection ratios recommended for:

(i) Colour and monochrome receivers receiving an N.T.S.C.-type colour transmission

(ii) Colour receivers receiving a monochrome transmission

2. THE CHOICE OF SUITABLE F.M. PARAMETERS

Before the experiments are described it is worth while to discuss the parameters of the waveform used to deviate the frequency of the wanted vision carrier.

First, the extent of the carrier frequency deviation must be limited so as to be below the level which would result in observable amplitude-modulation effects in the reproduced picture. Such effects are due to f.m. to a.m. conversion caused by the sloping characteristic of vestigial sideband receivers. Fig. 2 illustrates the ideal amplitude/frequency characteristic of such a receiver. In the region of the carrier the amplitude response is varying with frequency so as to cause a change in detector output of one part in 750 per kilocycle per second of carrier deviation. If the carrier frequency is subjected to a peak deviation of 1 kc/s by means of a low frequency sinusoidal wave, the effect upon the reproduced picture will be the same as that produced by an interfering signal, very near carrier frequency, whose amplitude is 57·5 dB below that of the carrier. From previous experiments[4] such an interfering signal must be some 50 dB below the wanted signal to satisfy the criterion of "just perceptible". Hence it may be deduced that the vision carrier frequency may be subjected to a maximum deviation of approximately 2·5 kc/s before f.m. to a.m. conversion effects are observed on a receiver conforming to the ideal characteristic of Fig. 2.

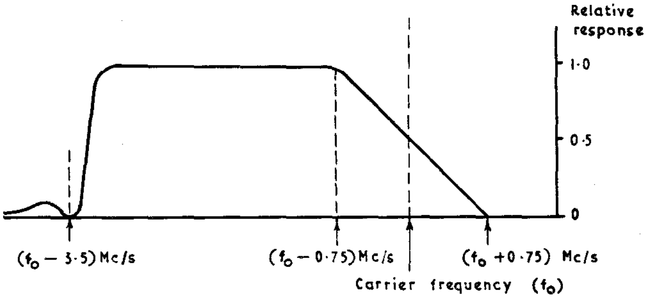

Fig. 2 - R.F. characteristic of vestigial side-band receiver

Secondly, in considering the choice of waveform used to deviate the wanted vision carrier, it must be remembered that the interference pattern observed is due to a signal produced at the receiver detector by heterodyning of the interference by the wanted vision carrier. In those circumstances, where the interference and the wanted vision carrier are modulated in amplitude but not in frequency, this heterodyne signal will produce a simple stripe pattern[5]. It can be argued that the visibility of the pattern will be reduced if the spectrum of the beat consists of many closely spaced lines. Such a condition may be met if either the wanted vision carrier or the interference is subjected to frequency modulation of high modulation index.

As previously discussed, the maximum usable vision carrier deviation should not exceed 2·5 kc/s and, in order to satisfy the requirement of high modulation index, the modulating frequency should be low. The choice of modulation frequency should be considered in terms of the following argument. The spectrum of a television signal is, for a stationary image, confined to a low frequency component at picture, field and line frequencies, together with a series of harmonics of the line frequency which are in turn modulated by field-frequency and picture-frequency components. Part of such a spectrum is illustrated in Fig. 3 showing one of the line-frequency harmonics

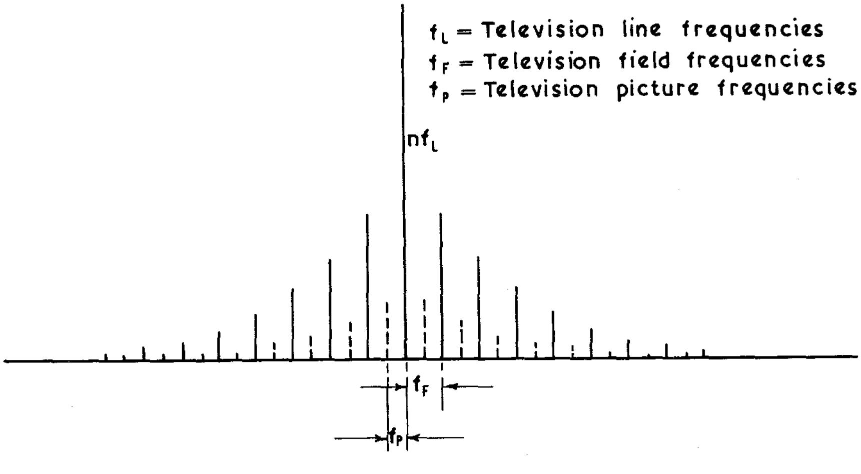
f_L = Television line frequencies
f_F = Television field frequencies
f_P = Television picture frequencies
nf_L
f_F
f_P

Fig. 3 - Television signal spectrum in the neighbourhood of a line harmonic

on either side of which smaller spectral lines indicate modulation at field and picture frequencies. An interfering signal resulting in a beat coinciding in frequency with the line harmonic (nf_L) will be reproduced with maximum visibility. If the interfering signal spectrum is to be distributed by means of frequency modulation, minimum visibility of the interference will be obtained when both the former interfering signal at the frequency nf_L is reduced to a small amplitude and the additional frequencies produced by deviation are non-coincident with the television spectrum lines. A frequency modulated wave of carrier frequency

$$\frac{\omega_0}{2\pi},$$

modulation frequency

$$\frac{\omega_m}{2\pi}$$

and modulation index m may be represented (in normalised form) by

$$\mathbf{J}_0(m)\sin\omega_0 t + \mathbf{J}_1(m)\sin(\omega_0+\omega_m)t - \mathbf{J}_1(m)\sin(\omega_0-\omega_m)t$$

$$+\ \mathbf{J}_2(m)\sin(\omega_0+2\omega_m)t + \mathbf{J}_2(m)\sin(\omega_0-2\omega_m)t$$

$$+ \ldots\ldots\ldots\ldots \text{ etc.}$$

where $\mathbf{J}_k(m)$, $k = 0, 1, 2 \ldots$ is the Bessel function of the first kind, of order k and argument m.

The value of modulation index m giving optimum reduction in visibility of the interfering beat should satisfy the condition that each of the Bessel coefficients in the above expression be small compared to unity. The requirement that the f.m. sidebands be non-coincident with the field and picture sidebands of a line harmonic suggests that the modulation frequency used for carrier deviation should not be multiples of 25 or 50 c/s, but such an ideal choice could involve problems of frequency stability. Alternatively, a modulation frequency may be chosen such that coincidence is permitted for a field or picture sideband frequency relatively remote from nf_L.

In the tests to be described, a modulation frequency of 195 c/s was used, thus resulting in a modulation index (for 2·5 kc/s peak deviation) of approximately 13*. For this frequency the first coincidence with the television spectrum occurs for the fifth order sidebands ($nf_L \pm 975$ c/s). Other values of m might have been used, including those for which $\mathbf{J}_0 = 0$, but in practice it is probably advisable to ensure that the beat frequency spectrum is distributed fairly uniformly in amplitude.

3. EXPERIMENTAL ARRANGEMENTS

For the experiments, the wanted vision signal was obtained from a low-power radio modulator driven by a signal generator whose output could be frequency modulated by an external oscillator.

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* $\mathbf{J}_0^{(13)} \simeq 0{\cdot}2$, $\mathbf{J}_1^{(13)} \simeq -0{\cdot}1$, $\mathbf{J}_2^{(13)} \simeq -0{\cdot}2$, $\mathbf{J}_3^{(13)} \simeq 0$, $\mathbf{J}_4^{(13)} \simeq 0{\cdot}2$, $\mathbf{J}_5^{(13)} \simeq 0{\cdot}1$

The interfering signal was injected into the feed to the receiver via an attenuator and a mixing pad. For a ratio of wanted signal to interference of 0 dB the peak value of the interference was adjusted to be equal to the peak white value of the wanted vision signal. Throughout the tests the wanted carrier frequency was 45·05 Mc/s and the signal e.m.f. for peak white modulation was 2 mV r.m.s. from a 75 Ω source impedance. A sound carrier on a frequency of 41·5 Mc/s was also provided having an e.m.f. of 1 mV r.m.s.

Two asymmetric sideband receivers were used (receivers 1 and 6 of Reference 2), namely:

(i) A 21 in. (53 cm) colour receiver, produced by the B.B.C. Research Department, employing a shadow-mask display tube and synchronous detection along the I and Q chrominance axes.

(ii) A 21 in. (53 cm) domestic monochrome receiver of good performance.

Observations were carried out for the following four conditions:

(a) A colour transmission with the colour receiver.

(b) A colour transmission with the monochrome receiver.

(c) A monochrome transmission with the colour receiver.

(d) A monochrome transmission with the monochrome receiver.

For the colour transmissions the wanted carrier was modulated with the 405-line N.T.S.C.-type waveform describing saturated colour bars: the monochrome transmission was obtained from this by removing the "burst" and chrominance signals.

The test procedure was as follows:

The receiver used was first tuned to the wanted signal in the absence of interference. The frequency of the interfering signal, nominally 45·5 Mc/s, was then adjusted to produce the most obvious pattern in the presence of the wanted signal. The amplitude of the interfering carrier was slowly reduced until the pattern was judged to be "just perceptible" by each of four experienced observers viewing at distances from four to six times picture height. Having noted the "just perceptible" amplitude for each observer, the test was repeated with the interfering carrier at various frequencies down to 42 Mc/s. All tests were carried out both with and without frequency modulation applied to the wanted vision carrier.

The results quoted in the next section are the averages for all four observers.

4. RESULTS AND DISCUSSION

The main series of experiments was carried out to ascertain the effect of implementing the proposal^3 in terms of the frequency modulation parameters discussed in Section 2 (i.e. the wanted vision carrier was subjected to a deviation of ±2·5 kc/s by a 195 c/s sine wave).

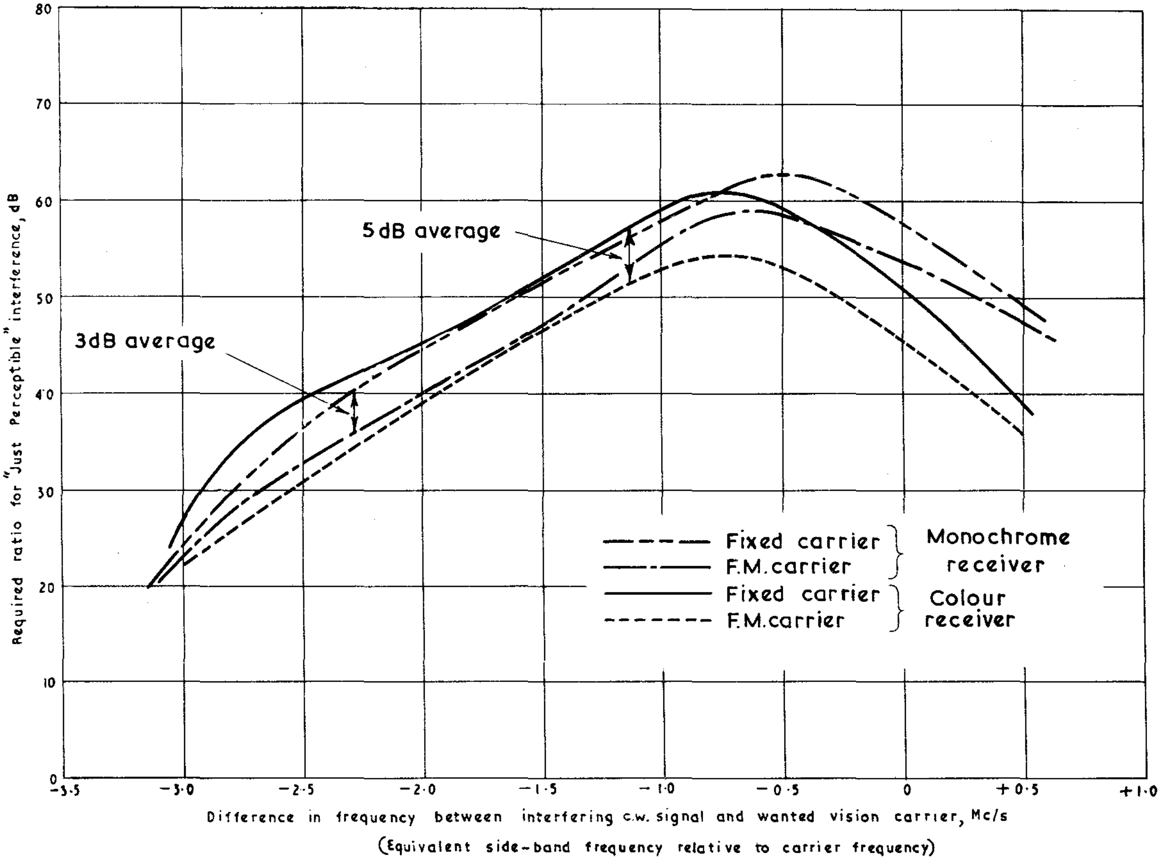

Fig. 4 - Required ratios for monochrome transmissions to colour and monochrome receivers

Tests were carried out using both the monochrome and colour receivers with monochrome and colour transmissions as detailed in Section 3. Fig. 4 illustrates the required ratios of wanted signal to interference for both receivers when used with monochrome transmissions. From the curves it would appear that, as viewed on the monochrome receiver, narrow band frequency modulation of the wanted carrier results in an average improvement of some 3 dB. The corresponding curves for the colour receiver show that, for the f.m. parameters used, the proposed arrangement leads to a greater improvement (some 5 to 6 dB) particularly for interference within the bandwidth of the receiver chrominance channel. An explanation has been given[2] describing the action of gated c.w. interference on the "colour killer" circuit, and if this portion of the receiver employs synchronous detection (as in the case of the colour receiver used in these tests) the "killer" will tend to remain operative when the beat between the interference and the vision carrier is frequency modulated. This might well account for the additional improvement obtained for interfering frequencies in the vicinity of the colour subcarrier. On the other hand, it is unlikely that such a large improvement would be obtained for more economically designed colour receivers where the "colour killer" circuit might well employ envelope detection.

Comparing the results obtained for both receivers, it has been noted that the proposal results in greater improvement when using the colour receiver. It is suggested that this might well be due to the integration of "scrambled" interference patterns by the longer afterglow of the colour tube. The results of an equivalent series of tests using a colour transmission as the wanted signal are shown in Fig. 5. On the monochrome receiver the small deviation of vision carrier frequency has resulted in an average improvement of some 3 dB in susceptibility to c.w. interference: for the colour receiver the average improvement again amounts to some 5 dB.

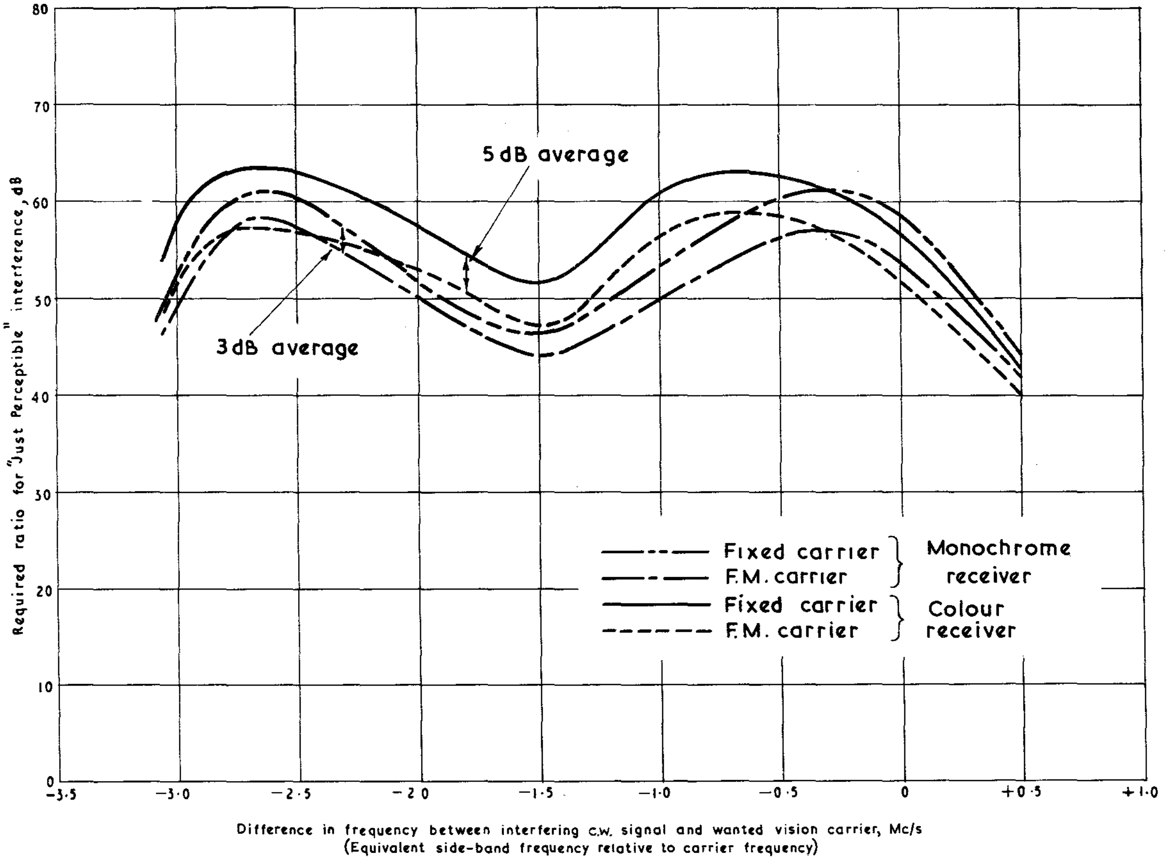

Fig. 5 - Required ratios for colour transmissions to colour and monochrome receivers

As a point of interest, a few further observations were made using the monochrome receiver and the colour transmission; this time, however, the wanted vision carrier frequency was fixed and it was the interfering signal which was subjected to the same f.m. parameters as had been used before in conjunction with the wanted signal. For all the observations made, this interchange resulted in the same ratios of wanted to interfering signal.

Having ascertained the effectiveness of the proposal in terms of certain frequency modulation parameters (which might be considered ideal), it was decided to investigate the effect of reducing the carrier deviation, as this might be necessary in a practical system. A further series of tests was therefore carried out using the monochrome receiver and a monochrome transmission only; the carrier deviation was reduced to ± 1 kc/s and the modulation frequency held at 195 c/s.

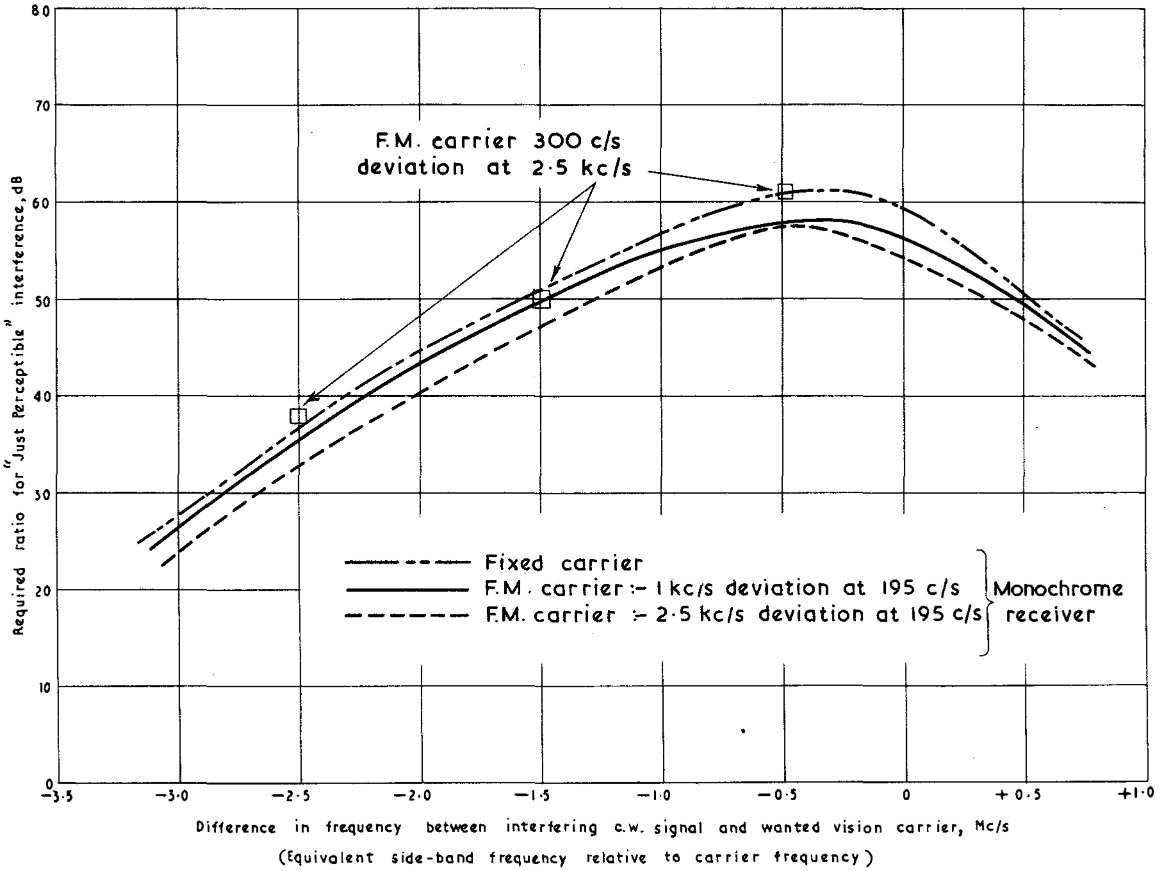

Fig. 6 - Required ratios for monochrome transmissions to monochrome receiver

Fig. 6 shows the results of these tests as compared with those obtained for a carrier deviated by ± 2·5 kc/s, and for fixed carrier operation. It will be noted that the reduction of deviation causes the average improvement to fall from 3 dB to approximately 1·5 dB.

A few additional tests were made using a very small modulation index (i.e. 300 c/s deviation at 2·5 kc/s). The results obtained are plotted as squares in Fig. 6. It will be seen that no reduction compared with the use of a normal fixed carrier was obtained in susceptibility to c.w. interference.

In general, the results obtained from the tests described above would indicate that the maximum benefit to be obtained from the proposed arrangement lies within the range from 3 to 5 dB for both 405-line monochrome and N.T.S.C.-type colour transmissions. In practice it is likely that several factors would limit its application. First, the variations of receiver amplitude/frequency characteristics for frequencies near to that of the carrier, together with those due to propagation, receiving aerials, etc., would probably demand a reduction in carrier deviation; if the deviation were reduced to approximately 1 kc/s the benefit obtained from the proposal would be marginal. Secondly, it must be remembered that the results quoted show the benefit obtained from the proposal when the frequency of the interference is adjusted to give a pattern of maximum visibility with the vision carrier fixed. If however, when using fixed carrier, the frequency of the interference is adjusted to give a pattern of minimum visibility[4, 6], the effect of carrier deviation is to render the pattern more visible. This is a serious disadvantage, since the principle of "off-set" carrier frequency is used for co-channel operation of television transmitters. A third factor arises when considering the application of the proposal to an N.T.S.C.-type colour transmission where, as is very desirable, the vision and sound carrier frequencies differ by an integral multiple of line scanning frequency. If the vision receiver does not reject the sound carrier adequately (possibly due to a tuning error) a signal of the difference frequency will appear at the vision detector and possibly at the display tube also. Interference produced by the beat between this difference signal and the colour subcarrier (bearing an odd multiple relationship with half the line frequency) will, therefore, itself bear an odd multiple relationship with half the line scanning frequency — a condition which results in minimum visibility.

If this "locked-carrier" system were to be retained it would be necessary to apply the same f.m. parameters to both vision and sound carriers, but unless a small deviation were used audible interference would result due to the relatively narrow bandwidth of the sound receiver. It is not possible to quote a figure for the maximum deviation permissible in such circumstances, since this would depend upon the receiver design and tuning, but for an average receiver a deviation of a few hundred cycles per second is probably all that could be used. The experiments have shown (see Fig. 6) that no improvement against c.w. interference would be obtained if the vision carrier deviation were so restricted.

In order to investigate an alternative to the "locked-carrier" arrangement discussed above, an experiment was carried out in which the sound carrier was fixed and the vision carrier, modulated by an N.T.S.C.-type colour-bar waveform, could be subjected to the f.m. parameters used in the main tests (2·5 kc/s deviation at 195 c/s). In the experiment the monochrome receiver was mistuned slightly so as to show an obvious interference pattern due to a beat between the colour subcarrier and that signal produced by inadequate rejection of the sound carrier. By very slight adjustment to the vision carrier frequency this interference pattern was arranged to have maximum visibility. Frequency modulation was then applied to the vision carrier, which resulted in an expected reduction of pattern visibility.

A comparison was made between this less obvious pattern and that obtained using the standard form of "locked-carrier" system. Of the two possible arrangements the "locked-carrier" system proved to be much more effective in reducing the visibility of the interference.

5. CONCLUSIONS

The experiments described in this report show that in general no greater protection against c.w. interference would be obtained by adopting the proposal put forward by E.P. Wethey.

For an interfering signal of frequency such as to produce a pattern of maximum visibility, f.m. applied to the wanted vision carrier would result in an improvement of 3 to 5 dB. On the other hand, for an interference pattern of minimum visibility, the effect of f.m. is decidedly disadvantageous. The latter would be true for interference between co-channel transmitters with "off-set" carrier frequencies.

Applied to an N.T.S.C.-type colour television transmission, the proposal would of necessity result either in reduced compatibility or, alternatively, audible interference with the sound channel.

6. REFERENCES

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